American Council for Renewable Energy Organizing Conference

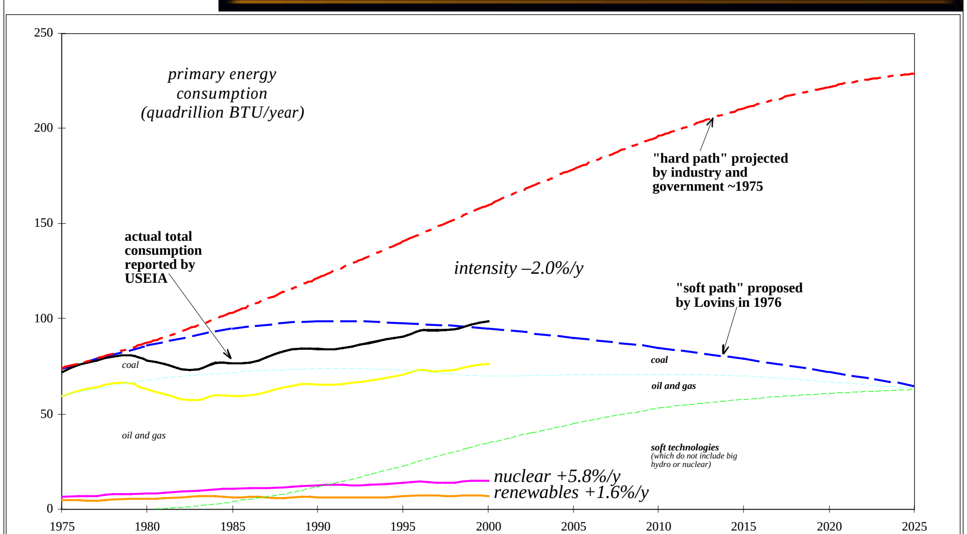
Keynote address, Washington, DC, 10 July 2002

Accelerating Renewables:

Expanding the Policy and Marketing Toolkit

Amory B. Lovins, CEO, Rocky Mountain Institute
(also Chairman of the Board, Hypercar, Inc.)
www.rmi.org, www.hypercar.com

U.S. energy/GDP already cut 40%, to very nearly the 1976 "soft path"...



but renewables have been mainly stalled for a quarter-century

End-use efficiency can spread quickly

- ◊ In 1983–85, 10 million people served by Southern California Edison Company (then the #3 U.S. investor-owned utility) were cutting its 10-years-ahead forecast peak load by 8 1/2% *per year*, at ~1% of marginal supply cost
- ◊ During 1979–85, U.S. GDP grew 16%, oil use fell 15%, and Persian Gulf oil imports fell 87%
- ◊ Lower energy intensity *vs.* 1975 is by now the biggest U.S. energy "source"—3× oil imports, 5× oil production, 13× Persian Gulf imports
- ◊ New efficiency and design techniques and marketing and delivery methods are even better

Efficient use can be further speeded by at least ten means

- ◊ The two conventional means: price and regulation (or its lack — laissez-faire competition/innovation)
- ◊ There are ≥ 8 more means too (ECE^3 keynote 6/01)
  - Ability to respond to price (barrier-busting)
  - What competes, what is rewarded (efficiency/supply competi-tion, correcting perverse incentives for utilities and designers)
  - What benefits are marketed and sought (many big side-benefits)
  - Technologies *vs.* negatechnologies (scrapping inefficient devices)
  - How designers think (tunneling through the cost barrier)
  - How quickly we deploy (mass retrofits, vernacular technologies)
  - How business is done (Natural Capitalism)
  - What drives demand for energy services (values, scorekeeping)
- ◊ If price isn't the only way to deploy efficiency, why should it be for more "visible" renewables?

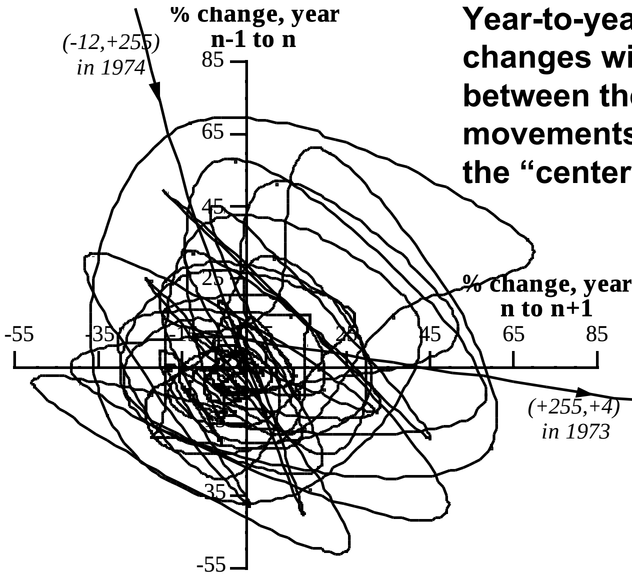
Conventional policy instruments for promoting renewable energy

- Regulation
  - Portfolio standards, mandates, deals (MN), results (Kyoto),...
  - Net metering, FERC transmission rules for intermittent sources,...
- Innovation + laissez-faire
  - RD&D, "golden carrots," targeted development
  - Green power, green tags, information, public education
  - "Competitive" restructuring, simply competing (Cypress PVs)
- Taxes and prices
  - Energy, carbon, and other Pigouvian taxes and emissions trading
  - Production tax credits, buydown subsidies, public financing,...
  - Tariffs and tariff structures, PURPA buybacks / feed laws,...
- These all work; choice is a matter of taste
- *How else* can renewables be promoted/accelerated?

How else can renewables, too, be accelerated?

- New policy imperatives: security, climate,...
- New ways of designing integrated systems
- New drivers / motivators / marketing tools
- Technical and policy innovations to grasp those opportunities
- New integration of domestic with global needs
- Aggregated purchases, *e.g.*, for PVs at GW scale
- Technological discontinuities in end-use efficiency, hydrogen, and vehicles that can make renewables far more valuable and convenient
- New policy frameworks and decision processes

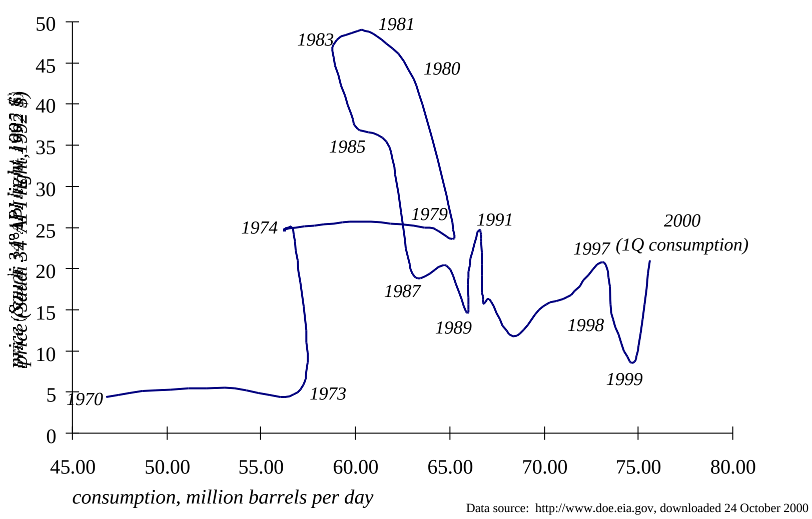
The Brownian Random Walk of World Real Oil Price, 1881–1993



Year-to-year percentage price changes with a one-year lag between the axes. If the price movements showed a trend, the "center of gravity" would favor a particular quadrant. All that happened after 1973 is that volatility trebled; changes stayed perfectly random, just as for any other commodity.

Graph devised by H.R. Holt, USDOE

Market surprise: world crude-oil real price *vs*. world oil consumption, 1970–2000



Data source: http://www.doe.eia.gov, downloaded 24 October 2000

Relative price doesn't drive all deployments of end-use efficiency

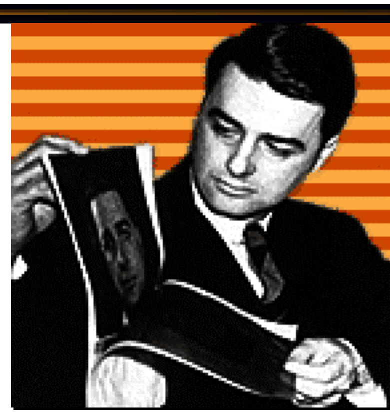
- Prices do matter, and should be correct, but ability to respond can matter more
  - Seattle in 1990–96 paid half Chicago's electricity price, yet saved kW_p 12× as fast and kWh 3,640× as fast, due to utility differences
- Price is only one of many ways to get attention: e.g., US E/GDP 1996–99 fell 3.2%/y (and el./GDP 1.6%/y) during record-low and falling prices
- Prices without barrier-busting do little
  - DuPont's European factories are as inefficient as US ones despite long exposure to prices 2× as high
- High energy prices not necessary and not sufficient
- Fear of oil depletion not necessary and not realistic
- If price isn't dispositive for deploying efficiency, why should it be for renewables, which are "sexier" and more visible?

Price matters, but may well become less important

- On the demand side, efficient use will be bought mainly for qualitatively improved services
- On the supply side, distributed / renewable resources will be bought mainly for their distributed benefits
- Outcomes will therefore become decreasingly predictable from relative prices
- Disruptive technologies may be driven mainly by wholly different factors, such as demand pull
- This isn't to say renewables can't compete on price: Cypress Semiconductor's 335-kW rooftop PV order pays even *without* reliability benefits or CA buydown! But rather, we should not be unduly fixated on price.

Edwin Land

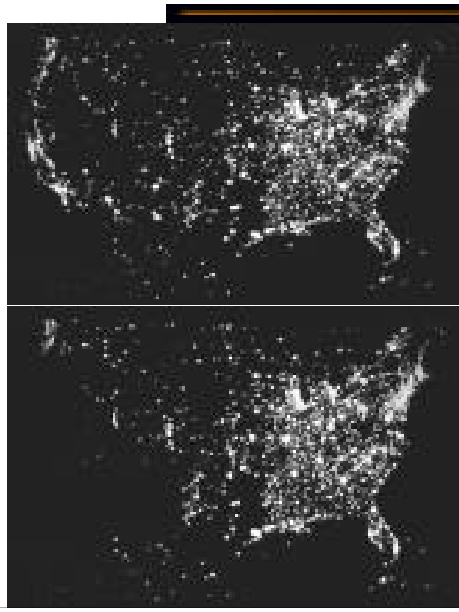
“People who seem to have had a new idea have often just stopped having an old idea”



12 new drivers for renewables

- National, regional/state, community, and individual security of supply and balance of trade
- Protection from disruptive price volatility
- Avoiding supply overshoot (hence price volatility)
- Climate protection, local environment
- New aggregations of purchasing, *e.g.*, for PVs
- Novel real-estate value propositions
- Local, Tribal, agricultural economic development
- Global economic development (hence security)
- Prestige, bragging rights, helping our kids, fun
- Powerful “distributed” trend in electric generation
- Efficiency & H_2 transition raise renewables’ value
- New approaches to the national policy process

9/11 reminds us of the importance of resilient system architecture



EPRI-website synthetic satellite image, 10 August 1996...utilities routinely keeping the lights on. But ~98–99% of U.S. outages are caused by the grid. *E.g.*:
35 seconds later, after an Oregon powerline sags into a tree limb, operational goofs & poor communications black out 4 million people in nine Western states and parts of Canada. (Local supply prevents that — and up to 95+% of grid failures are in the distribution system)

Reliable electricity in a dangerous world

"Aside from its obvious environmental benefits, solar and other distributed energy resources can enhance our energy security. Distributed generation at many locations around the grid increases power reliability and quality while reducing the strain on the electricity transmission system. It also makes our electricity infrastructure less vulnerable to terrorist attack, both by distributing the generation and diversifying the generation fuels. So if you're engaged in this effort, it is my view that you are also engaged in our national effort to fight terrorism."

— David Garman, U.S. Assistant Secretary of Energy for Efficiency and Renewable Energy, 2 October 2001

Renewables for security

- *Brittle Power* (www.rmi.org, 1981 RMI report to DoD); need efficient, diverse, dispersed, renewable
- Military applications; ACRE' work w/security prof'ls.
- Regional and state policy / diversified portfolios
- Urban policy, *e.g.*, San Francisco's $100M bond
- Project developers, *e.g.*, windfarms (on/offshore)
- Real-estate developers, *e.g.*, Durst, Real Energy, Astro-Power/Shea, Beazer Homes "Powerhouse"
  - Different-colored "ultrareliable" power sockets; expandable kW
  - Resilient, gracefully/reversibly islandable inverters
- Commercial/industrial PV retrofits, *e.g.*, PowerLight

Renewables are constant-price

- Many of the 17 states that have been restructuring their electricity sector have already experienced strong price volatility (catastrophically in CA)
- Short-run social *value* of el. is $\geq 10^2\times$ long-run *cost*, and restructuring bases el. price on value, not cost, but political system won't tolerate $\geq 10^2\times$ price jumps
  - Withholding supply can be extremely lucrative
  - Market price limited only by FERC or by customer assets — or by aggregating distributed resources and shorting the market!
  - Resulting losses dwarf inefficiencies of a well-regulated monopoly
- Renewables dilute or eliminate these price risks
- Bundled or unbundled, the constant-price attribute must be captured, not lost/socialized in mere ¢/kWh

Avoiding supply overshoot

- Efficiency improvements can be fast
- Traditional supply expansion is slow
- Most people buy efficiency because it's cheaper
- So efficiency often outruns supply, reaching the "finish line" first and taking the revenues meant to pay for supply, bankrupting suppliers
- CA & U.S. did so 1985–86; no use watching this very bad movie all over again (as Admin. urges)
- Many renewables are fast too, further risking conventional supply...but decreasing risk to users
- Collapsing merchant-plant finance isn't just Enron — new combined-cycle plants are uneconomic

Corporate leadership in profitable climate protection

- DuPont (worldwide), 2000–2010
  - Revenue +6%/y, energy use at worst constant
  - 1/10 of energy, 1/4 of feedstocks renewable
  - 2010 greenhouse gas emissions = 1990 – 65%
- STMicroelectronics (#4 in the world)
  - Zero net carbon emissions by 2010, incl. rens. & offsets
  - CO_2/chip –92% profitable now, –98–99% soon
  - Fabs build faster and cheaper, work better
- BP: met 2010 CO_2 goal (1990 – 10%) in 2002 at a net "cost" of –US$0.65 billion
- All in the name of shareholder value
- Now renewables are starting to join too

By 2050, an affluent world could meet or beat a 3–4× C reduction goal

× 2 × 3–4 ÷ 2–4

$$C_{energy} = \frac{\textit{population} \times \textit{affluence per capita} \times \textit{carbon}\ \text{intensity}}{\text{conversion eff.} \times \text{end-use eff.} \times \text{hedonic eff.}}$$

× 1.5 × 4–6 × 1–2?

or ~1.5–12× lower CO_2 emissions despite assumed 6–8× growth in GWP. (A 1993 UN study* found 1.35× and 8× respectively, 1985–2050.) Great flexibility is thus available. The future is not fate but choice.

*Johansson, Kelly, Reddy, Williams, & Burnham, *Renewable Energy*, 1177 pp., Island Press, Washington DC.
This analysis, though mostly excellent on the supply side, assumed relatively weak end-use efficiency opportunities.

Beyond green-power purchasing

- In a tripolar world (government, business, and an Internet-empowered civil society), there are creative opportunities for new alliances that aggregate demand, *e.g.*, for GW-scale blocks of PV purchases, to cut cost dramatically*
  - Crack chicken-and-egg problem, set up sustained growth
  - Potential CA initiative to aggregate 1.5 GW of CA-made and -installed private-sector PV leadership purchases within 6 y, bringing array cost to $2/$W_p$; obvious scope in other states, sectors, multinational firms, and countries
  - UNEP wants to aggregate purchases by developing-country utilities to buy 0.5-1.5 GW/y of PVs
- Finally an idea whose time has come

*Free draft from info@solarcatalyst.com

Local environment often drives siting and purchase decisions

- ◊ Renewables can avoid air-quality, noise, and other local impacts of e.g. engine generators
- ◊ Local renewables are inherently more equitable because the same people automatically get both the energy and its side-effects
- ◊ Biofuels from sustainable feedstocks can be designed into natural-systems agriculture, enriching topsoil (and being paid for taking carbon out of the air and putting it back in the soil)
- ◊ Same (probably) for restorative forestry

Four Times Square, NYC

(Condé Nast Building)

- 1.6 million ft^2; 47 stories
- non-toxic, low-energy materials
- 40% energy savings/ft^2 despite doubled ventilation rates
- Gas absorption chillers
- Fuel cells
- Integral PV in spandrels on S & W elevations
- Ultrareliable power helped recruit premium tenants at premium rents
- Fiber-optic signage (signage required at lower floor(s))
- Experiment in Performance Based Fees rewarding savings, not costs
- Market average construction cost

Novel real-estate value propositions

- Buildings less (or not) dependent on the grid
  - E.g., big Federal office planned in Victoria, B.C. — off-grid
- Leases with no utility cost; wraparound financing
- Climate-neutral/-positive buildings (& firms)
- Longer-lasting, better-insulated roofing
  - Could even integrate PVs with Cool Roof passive cooling and with skylights, also probably eliminating skylight leaks — then sell the [nearly all surplus] PV output at onpeak prices
- Houses with ultrareliable power supply options
- Buildings with no trenches — no pipes or wires in the ground — cheaper for society (and builder?)
  - Greater siting/timing flexibility, better developer cashflow
  - But don't let tempt you to build where you shouldn't!
  - Important implications for developing countries too (S.Afr.,...)

Economic development

- Local: get jobs and multipliers from making and installing renewables, stop outflow of fuel dollars
- Tribal: some of poorest Native communities have richest renewables — 250 GW wind just in SD/ND
- Agricultural: vital boost to net farm/ranch income
- Regional: greatly increase value of hydropower and other renewables via hydrogen transition
- Global: reduce oil cashflow (destabilizing at both ends), free foreign relations, speed global development (especially for women), save and reinvest village cashflow to bootstrap development, improve global equity and security, avoid costly climate change, leapfrog many technologies

"Not Easily Expressed in Dollars" (NEEDS)

- Albertan PV expert Gordon Howell, P.Eng., has a client, Hélène Narayana, who's installing a 100-W_p home system for ~US$11/$W_p$ (Canada has only ~120 grid-connected home PV systems)
  - Enormous, bizarre institutional barriers — but this persistent client is serving as the lever to pry them open
- She's quantified the probability-adjusted values she places on improving her neighborhood and world, improving her image (with herself, neighbors, daughter), being a leader, having fun, etc.
- It adds up to US$5,650/y, and she's willing to buy a PV system costing 10 y of such benefits
- So her value system yields…a 2.3-month payback!

It's not about affordability

- Gordon Howell also notes that bundling the operating costs of your car with the cost of a 2.3-kW PV system (like his US$17k one) can yield paybacks as low as 7 months
- For instance, a new Chevrolet Cavalier + his PV system costs the same after 7 years as a Chrysler Intrepid—which means that the "payback" on the bundle is 7 years. So anyone driving a Chrysler Intrepid would have been able to afford a PV system if they had chosen to drive a Cavalier instead
- So PV choice isn't about affordability — only about the personal choices we make, hence about education and awareness

Electricity supply: the surprises are coming

- ~1880–1980: power stations costlier & less reliable than the grid, so must be shared via the grid
- ~1980– : power stations cheaper & more reliable than the grid, so really cheap and reliable supply must be at/near customers, *i.e.*, "distributed"
- Central thermal power plants stopped getting more efficient in the 1960s, bigger in the 1970s, cheaper in the 1980s, and bought in the 1990s
- New distributed technologies growing rapidly
- Capital market prefers their far lower risk
- A dozen forces are driving distributed architecture

Renewables are entering rapidly

- Europe plans 22%-renewable electricity by 2010
- Wind (30%/y) & photovoltaics (~26–42%/y) are the world's fastest-growing energy supply technologies
- Global wind capacity 24 GW at end 2001, adding ~6 GW/y (faster than nuclear grew in '90s); it's 18% of Denmark's power today, sometimes >100% locally
- 10^3s microturbines shipped; 200-kWe phosphoric-acid fuel cells costly (US$2–4/W) but worthwhile, so cheap polymer fuel cells will be even more attractive
- PVs, esp. bldg-integrated, starting very fast "liftoff," can compete onpeak on many new U.S. houses in ~2003–05; ~$0.05/kWh is plausible long-term

"Distributed benefits" change the game

- *Small Is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size* (RMI, 8/02; to be announced on www.rmi.org)
- Codifies and quantifies 207 "distributed benefits" that collectively increase the economic value of decentralized generation by typically ~10× (but exact value is always site-/technology-specific)
- So PVs can often be cost-effective now (without subsidy) if distributed benefits are fully counted
- *Cleaner Energy, Greener Profits* (RMI, 2001, www.rmi.org) applies this approach to fuel cells

Whence the order-of-magnitude typical value increase?

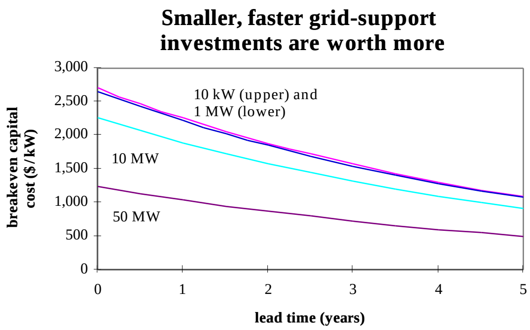
- Financial-economics benefits: often nearing ~10× renewables, ~3–5× others
- Electrical-engineering benefits: normally ~2–3×, far more if the distribution grid is congested or if premium power reliability/quality is required
- Miscellaneous benefits: often around 2×, more with thermal integration
- Externalities: indeterminate but may be important; not quantified here

Most investors don't yet properly count most of these distributed benefits. They should.

207 Distributed Benefits: ~10× Value

(Actual Value Is Very Technology- & Site-Specific)

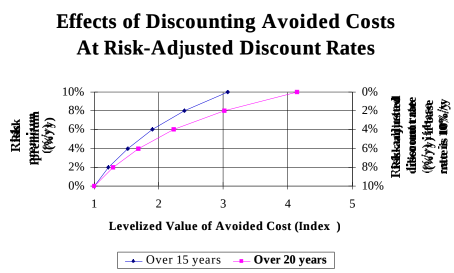
- ~10[1]×: Minimizing regret (financial ecs.)
  - Short lead times and small modules cut risk
    - Financial, forecasting, obsolescence
    - Overshoot and "lumpiness"



Tom Hoff's analytic solution shows that it's worth paying ~2.7× more per kW for a 10-kW overnight resource than for a 50-MW 2-y resource

Financial-Economics Benefits (cont'd)

- Portable resources are redeployable where needed
  - Benefits' expected value rises, risk falls
- Rapid learning, mass-production economies
- Constant-price resources *vs.* volatile prices
  - Risk-adjusted discounting can nearly double the present value of a gas cost stream for fair comparison with windpower
- Genuinely diversified supply portfolios (EU)
- "Load-growth insurance" of cogeneration & efficiency



Twelve drivers of distributed utilities

- ◊ "Distributed benefits" sharply raise value
- ◊ Supply-side advances
  - Superefficient end-use → less/cheaper supply
  - Onsite cogen/trigen: microturbines, phosphoric-acid fuel cells,...
  - Polymer fuel cells in buildings, plug-in parked Hypercars,...
  - "Hydro-Gen," renewable/carbon-free H_2, sustainable biofuels
  - Building-integrated/"vernacular" PVs, cheap windpower, other competitive renewables
  - 96+%-efficient electric storage (flywheel/ultracap), reversible FCs
- ◊ Grid and control advances
  - Advanced switches/telecom let automation of the distribution grid shift topology from unidirectional tree to omnidirectional web
  - Pervasive real-time energy and stability pricing, customer communication; "out-of-control" distributed intelligence?

Twelve drivers (continued)

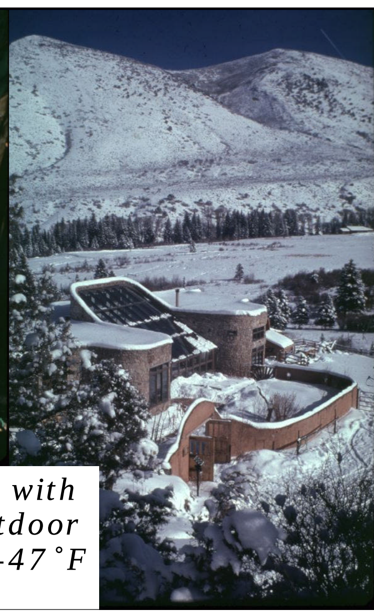
- ◊ Market/institutional advances
  - Competition values many previously unmonetized distributed benefits
  - So does unbundling power quality & reliability, grid stability, cost control,...
  - New market entrants better understand needed disciplines (financial economics,...)
  - Local Integrated Resource Planning (LIRP, being done by >100 North American electric utilities) prospects for distributed benefits; now Energy Resource Investment Strategy (ERIS)
    - Aim demand-side and distributed resources like a rifle, not a shotgun—target to defer/avoid costly grid investments
    - Ontario Hydro's first 3 experiments cut capital needs up to 90%, saved C$0.9b
- ◊ All twelve drivers reinforce each other, *regardless* of electricity-industry restructuring outcomes

Negawatts cost less than megawatts:
some recent building examples

- Comfort without heating or cooling, –47 to 115°F (RMI, Davis/Stanford Ranch ACT^2), at lower cost
- 90% a/c saving in new Bangkok house, same cost
- 90% home el. sav., 10-month payback in 1983
- Big office buildings: 80–90% less energy, build ~3–5% cheaper and 6 months faster, superior comfort and market performance
- 75% energy savings retrofittable in big Chicago office tower, same cost as just 20-year renovation
- 97% a/c saving design for retrofitting a CA office
- Similarly dramatic industrial new/retrofit savings

Rocky Mountain Institute's HQ

27 banana crops with no furnace at outdoor temps. down to –47˚F



- 7100' high, near Aspen
- "Winter and July"
- Frost possible on any day
- 39-day continuous winter cloud
- Integrated design
- Superinsulated (R-40/-80), superwindows (R-8–12 center-of-glass), ventilation heat recovery, 99% passive ht
- 95% daylit
- Superefficient equipment

Saved (1983 technology):

- 99% of space & water htg. energy, 50% H_2O
- 90% of home electricity (~$5/month) — av. load ~120 W for 4,000 ft^2
- PVs make ≥ 5× home use
- 10-month eff'y. payback
- Market-average cost

PG&E ACT² House
Davis, California

- Comfort without air conditioning at +113°F, even in a 3-day heat storm
- Mature-market building cost $1,800 lower
- Present-valued maintenance cost $1,600 less
- Design energy savings ~82% below California Title 24 (1992)
- Last 7 improvements justified only by savings of energy plus capital cost (last 1.5 t of a/c), not of energy alone
- Saved 3/4 of wall wood
- Would make a terrific combination w/ roof-integrated PVs

Industrial opportunities

◊ Save half of motor-system electricity (3/8 of all industrial electricity), retrofit aftertax ROI 100–200%/y

◊ Similar returns saving >50% of chip-fab HVAC power

◊ Pumping loop saves 92%, costs less, works better

◊ Retrofit refinery, save >40%, >80% pretax ROI

◊ Redesign new chemical plant, save ~3/4 of el., cut construction time & cost by ≥ 10% (the potential in new chip fab or data center is probably larger)

◊ Redesign supermarket, save 70–90%, costs less

◊ So...less supply needed, better thermal/el. balance, synergies when bundling efficiency with renewables

Negawatts partner with megawatts

- The less electricity you need, because you use it more efficiently, the smaller, simpler, and cheaper the supply can be
  - Hot-water-saving house has very high solar-water-heat fraction with a small collector (*e.g.*, 99% in Rockies)
  - Electricity-saving house needs only a few m^2 of PVs; CFLs make solar light affordable for ≥ 2 billion people
  - Passive-solar, daylit building needs little electricity, and can pay for even costly forms of onsite generation (PVs) by downsizing or eliminating HVAC systems
  - Similarly in other end-use applications and sectors
  - Big marketing advantages, *e.g.*, U.S. PV/grid houses
- Efficiency opens new horizons in marketing distributed generation — *e.g.*, PowerLight's PVs + efficiency ("PV+EE")bundle

Bundling PVs with end-use efficiency: a recent example

- Santa Rita Jail, Alameda County, California
- PowerLight 1.18 MW_p project, 1.46 GWh/y, ~3 acres of PVs
- Integrated with Cool Roof and ESCO efficiency retrofit (light-ing, HVAC, controls, 1 GWh/y)
- Energy management optimizes use of PV output
- Dramatic (~0.7 MW_p) load cut
- Gross project cost $9 million
- State incentives $5 million
- Gross savings $15 million/25 y
- IRR >10%/y (Cty. hurdle rate)

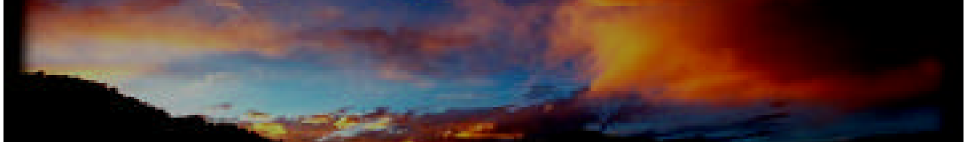
5×-more-efficient midsize SUV

an illustrative, costed, manufacturable, and uncompromised concept car (11/2000) developed for a few million dollars in 8 months by Hypercar, Inc. (www.hypercar.com), on time and on budget, with attributes never before combined

- ◊ 5 big adults, up to 69 ft³ of cargo
- ◊ hauls 1/2 ton up a 44% grade
- ◊ 1,889 lb (47% mass of Lexus *RX300*)
- ◊ head-on wall crash @ 35 mph doesn't damage passenger compartment
- ◊ head-on collision with a car 2× its mass, each @ 30 mph, prevents serious injury
- ◊ 0–60 mph in 8.2 seconds
- ◊ 99 mpg-equivalent (5× *RX300*)
- ◊ 330 mi on 7.5 lb of 5-kpsi H_2
- ◊ 55 mph on just normal a/c energy
- ◊ zero-emission (hot water)
- ◊ sporty, all-wheel digital traction
- ◊ ultra-reliable, software-rich, flexible
- ◊ wireless diagnostics/upgrades/tuneups
- ◊ 200k-mile warranty;no fatigue, rust, dent
- ◊ competitive manufacturing cost expected
- ◊ decisive mfg. advantages—≤ 90% less capital, space, assembly, parts count
- ◊ production ramp-up could start ~2006

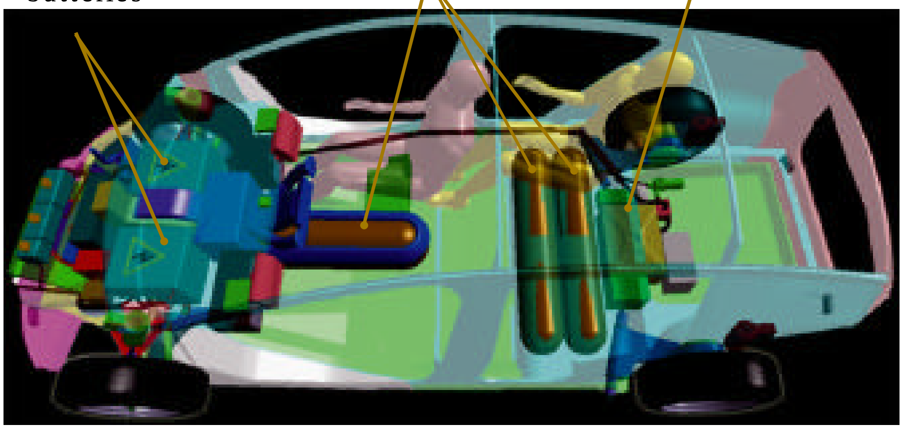
Ultimate public benefits of quintupled light-vehicle fuel efficiency

- ◊ Oil savings: U.S. potential = 8 Mbbl/day = 1 Saudi Arabia = 42 Arctic National Wildlife Refuges; world potential = 1 nega-OPEC
- ◊ Decouple driving from climate change and smog
  - ○ Profitably deal with ~2/3 of the climate challenge
- ◊ Lead a fast transition to a hydrogen economy
  - ○ Can be profitable at each step; adoption already starting
- ◊ Parked cars serving as plug-in "power stations on wheels" when parked (av. ~96% of the time)



"We'll take two." — *Automobile* magazine

55 mph on same power as normal a/c, so ready now for direct hydrogen fuel cells



Rapid, profitable **H_2 transition**

- Put fuel cells first in buildings for co-/trigen
  - Fuel with natural-gas reformers (or off-peak electrolyzers)
- Meanwhile introduce H_2-ready Hypercars
  - Fleets (return nightly to the depot for refueling)
  - General market: start with customers who work in or near the buildings that by then have fuel cells
    - Use buildings' hydrogen appliances for refueling
      - Sized for peak building loads that seldom occur
    - Sell kWh and ancillary services to grid when parked
      - Marginal investment in H_2 compression/fueling, grid connection, more durable PEMFC is modest
    - Earn back much/most of cost of car ownership
      - U.S. full-fleet potential ~5–10 TW, ~6–12× grid cap.

Rapid, profitable H_2 **transition (2)**

- Meanwhile, hydrogen appliances get cheaper, so put them outside buildings too
  - At filling stations—a much better business than gasoline
    - Use two ubiquitous, competitive retail commodities — CH_4 and el. — and play them off against each other
    - Use just the offpeak distribution capacity for gas and electricity that is already built and paid for
  - The capital intensity of a U.S. miniature-natural-gas-reformer fueling infrastructure is *less* than that of just sustaining the existing gasoline fueling infrastructure
  - As both hydrogen and direct-hydrogen fuel-cell vehicles become widespread, bulk production and central distribu-tion of hydrogen may become justified

Rapid, profitable H_2 **transition (3)**

- ≥ 2 proven, climate-safe, cost-effective methods
  - Reform natural gas at the wellhead and reinject the CO_2
    - Reforming (~5% of US gas now) & reinjection are mature
    - Potentially three profit streams: H_2, $+CH_x$, $-C$
    - Strong industry interest (BP, Shell, Statoil), 200-y resource
  - Electrolyze with climate-safe electricity
    - Greatly improves economics of renewable electricity
      - Even US gasoline ($1.25/gal) is equivalent at the wheels to $0.09–0.14/kWh electricity with a proton attached to each electron — so run dams in “Hydro-Gen” mode, shipping compressed hydrogen instead of kWh
      - H_2 storage makes wind/PV power firm & dispatchable
- Probably more: coal (BP/Princeton), direct photolysis, novel biofuels, other renewables,...

Policy innovations needed

- Efficiency and supply, renewables and nonrenewables, big and small, should compete fairly and symmetrically in all admin. & market processes
- Regulated energy distributors should be reward-ed (as 9 states used to, 1–2 do now) for reducing customers' bills, not for selling more energy
- Distribution companies should be able to own and operate distributed generation
  - But not unfairly game or leverage their fuel, customer, grid, or pollution-credit capabilities, assets, and relationships
- Real-time pricing justifies CA PVs with no subsidy
- Barriers to thermal integration should be purged
- Interconnection should be simple, plug-and-play
- Hydrogen transmission/storage/use needs modernized regulation in time to avoid barriers

How do political leaders choose?

- Most of the action is state and local, but national policy sets context — can help or hurt non-Federal initiatives
- Current Federal policy is at best seriously incomplete
- National Energy Policy Initiative, www.nepinitiative.org
- Start with principles & objectives, focus on agreement
- Organized by two nonpartisan nonprofits, 2001–02
- Funded at arm's-length by seven foundations
- Interviewed 75 diverse constituency leaders
- Convened 22 bipartisan energy policy experts
- Reached broad consensus on vision, goals, and strategies; suggested innovative and win-win policy options
- Bipartisan bicameral release 14 March, EESI 26 June
- Encouraging for a fractured Congress

Policy wildcatters drill through thick strata of partisan polarization…and strike a gusher of consensus

- Endorsed by 33 bipartisan energy leaders so far
  - Half are or were senior energy-industry executives
  - Others' backgrounds include:
    - Two Presidential advisors, two Dep. Secs. of Energy
    - Five Subcabinet members (State, Com., En., DoD, EPA)
    - A CIA Director, a House energy leader & his deputy
    - Two senior economists of President's CEA
    - Chairs/members of 2 Fed. & 3 State en. reg. commns.
- Meeting America's energy, economic, environmental, and security needs simultaneously and without compromise…by building on the consensus that already exists but remains largely unacknowledged

A bigger portfolio of tools…

- Works better
- Happens faster
- Engages more diverse actors across society
- Has broader, more trans-ideological appeal
- Is more widely adaptable/applicable globally
- Integrates better with many other needs
- Learns faster
- Is more fun

"People and nations behave wisely —
once they have exhausted all other alternatives."
— Churchill

"Sometimes one must do what is necessary."
— Churchill

"We are the people we have been waiting for."
— Hopi Elders

www.rmi.org

Thank you! To dig deeper...

- U.S. energy overview: "Mobilizing Energy Solutions" and "Energy Forever," www.rmi.org/sitepages/pid171.php
- Advanced energy efficiency, green buildings, etc.: www.natcap.org, www.rmi.org, and www.esource.com
- Hypercars: www.hypercar.com and www.rmi.org/sitepages/pid386.php
- Hydrogen transition: www.rmi.org/images/other/HC-StrategyHCTrans.pdf
- Barrier-busting to speed up efficiency: www.rmi.org/images/other/C-ClimateMSMM.pdf
- Energy security: www.rmi.org/sitepages/pid533.php
- Distributed benefits and fuel cells: "Cleaner Energy, Greener Profits," www.rmi.org/sitepages/pid171.php
- National Energy Policy Initiative: www.NEPInitiative.org

About the author: A consultant experimental physicist educated at Harvard and Oxford, Mr. Lovins has received an Oxford MA (by virtue of being a don), seven honorary doctorates, a MacArthur Fellowship, the Heinz, Lindbergh, World Technology, and Heroes for the Planet Awards, the Happold Medal of the UK Construction Industries Council, and the Nissan, Mitchell, "Alternative Nobel," Shingo, and Onassis Prizes; held visiting academic chairs; briefed 16 heads of state; published 28 books and several hundred papers; and consulted for scores of industries and governments worldwide, including the oil industry since 1973, DOE, and DoD. *The Wall Street Journal*'s Centennial Issue named him among 39 people in the world most likely to change the course of business in the 1990s, and *Car* magazine, the 22nd most powerful person in the global automotive industry. His work focuses on whole-system engineering; on transforming the car, energy, chemical, semiconductor, real-estate, and other sectors toward advanced resource productivity, and on integrating resource efficiency into the emerging "natural capitalism."

About Rocky Mountain Institute (www.rmi.org): This independent, nonpartisan, market-oriented, technophilic, entrepreneurial, nonprofit organization was cofounded in 1982 by its co-CEOs, Hunter and Amory Lovins. RMI fosters the efficient and restorative use of natural and human capital to create a secure, prosperous, and life-sustaining world. The Institute's ~50 staff develop and apply innovative solutions in business practice, energy, transportation, climate, water, agriculture, community economic development, security, and environmentally responsive real-estate development. RMI's ~$6-million annual budget comes roughly half each from programmatic enterprise earnings (mainly private-sector consultancy) and from foundation grants and donations. Its work is most recently summarized in *Natural Capitalism* (w/Paul Hawken; 9/99, www.natcap.org).

About Hypercar, Inc.: In August 1999, Rocky Mountain Institute transferred most of its internally incubated technical activities on Hypercar vehicles to this partly-owned second-stage for-profit technology development firm, its fourth spinoff. Funded by private investors, Hypercar, Inc. (www.hypercar.com) pursues business opportunities related to the Hypercar concept developed at RMI since 1991. To declare an interest, Mr. Lovins is a minor holder of equity options in the firm.